corrugated pattern interrupted at repeated intervals to include a fold line for facilitating folding of said plates, said fold lines parallely disposed along said length of each of said plates, said corrugated pattern on a first plate arranged at a right angle to said corrugated pattern on an adjacent, second plate,

wherein said angle of said ridges and channels between facing sides of adjacent plates creates [is adapted to create] a flow resistance to said respective fluid medium flowing over said respective side of said plate such that the flow resistance is greater in said lengthwise direction of said packing than said widthwise direction.

R E M A R K S

The Examiner claimed that the numbering of the claims was not in accordance with 37 C.F.R. § 1.126; Claims 10 and 11 were renumbered as 5 and 6, respectively.

Newly submitted Claim 6 was not considered because it was said to be directed to a distinct invention from the invention originally claimed and has been cancelled.

Claim 5 was rejected under 35 U.S.C. § 103(a) as being unpatentable over *Herrmann* or *Hultgren* in view of *Usher*.

The Examiner claimed that *Herrmann* or *Hultgren* disclosed all the claimed limitations except for the ridges and channels forming at least a 45 degree angle with respect to the length of the plate.

He also claims *Usher* discloses a heat exchanger for two fluids comprising a plurality of rectangular plates (Figures 3 and 4), wherein the angle of the ridges and channels are 30 degrees with respect to the width of the plate (i.e. 60 degrees with respect to the length of the plate) for the purpose of improving heat exchange (Page 3, lines 31-49).

He then reasoned that since *Herrmann* or *Hultgren* and *Usher* are both from the same field of endeavor, the purpose disclosed by *Usher* would have been recognized in the pertinent art of *Herrmann* or *Hultgren*, making it obvious to a person in the art to employ in *Herrmann* or *Hultgren*, ridges and channels having an angle of 60 degrees with respect to the length of the plate for the purpose of improving heat exchange as recognized by *Usher*.

Claim 5 was also rejected under 35 U.S.C. § 112, second paragraph, as being indefinite for the recitation of the limitation "said first and second medians" in line 9, and lack of antecedent basis for this limitation.

The references of *Herrmann* or *Hultgren* were also said to disclose inlet and outlet ports located at the corners of the casing.

The Applicant has carefully reviewed the cited art in connection with the Examiner's reasons for rejection and has amended Claim 5 accordingly.

Claim 5 now reflects a heat exchanger having a heat exchanger bundle that is accordingly shaped due to the repeating fold lines incorporated into the plate material so to allow the formation of a plurality of plates. None of the references, either alone or in combination, show a heat exchange bundle incorporating such fold lines, and the Applicant believes the present device is not obvious in view of the cited art for the following reasons.

A conventional plate heat exchanger is typically formed by a stack of individual plates sealed together by gaskets along the perimeter of each plate. The two fluid mediums flow between the plates in alternate layers so that heat can be transferred between them through the plates. The flow typically enters each layer through holes in the corners of the plates thereby forming ducts through the stack. By using gaskets around the hole perimeters at every second slot between the plates, the two fluid flows can be separated from each other and made to flow through every second slot between the plates. This is the type of heat exchanger described by *Usher* (UK 1339 542)

although the gaskets are not shown in the figures. It can be appreciated that proper function of these gaskets is crucial for performance of the heat exchange process. Each plate has its own set of gaskets which are to be individually placed during assembly; the fluid media can be described as flowing between the corners of the stack.

In the present invention, the two flow mediums are also made to flow through many inter-spaced layers, each flowing from one corner of the stack and to another. The present stack however is made from one continuous band of material that is folded in an accordion fashion and not from individual plates. The flows do not enter through holes in the stack, but enter in from the sides of the stack. The folded geometry then automatically separates the two flows to alternating layers without requiring holes in each plate, nor the individual gaskets. The structural differences of the present device are:

1. Simple and inexpensive design from one continuous strip of material;
2. No holes in the material of each formed sheet;
3. Simplified sealing, with no need for individual gaskets.

Further, in the simple theory for recuperative heat exchangers of the *Usher* type, the heat transfer at a given temperature difference between the media is given by the product of heat transfer surface area and heat transfer coefficient. *Usher* designated these factors as A and U respectively, and elaborates about the importance of the heat transfer coefficient and how it is influenced by turbulence created by the pattern of the plates. In fact, the *Usher* invention is mainly concerned about how a variety of plates with different heat transfer coefficients can be created by means of a press tool with interchangeable parts. *Usher* discusses providing differing angles of corrugation in order to provide differing degrees of heat transfer, but *Usher* is not concerned with maximizing heat transfer through regard of the actual distribution of flow.

Turbulence will not only cause good heat transfer, but will also create undesirable friction, resulting in pressure loss for the flow. It constitutes a classic problem in fluid dynamics to find a way of getting as much heat transfer as possible and at the same time, keeping the friction losses as low as possible. Relatedly, the purpose of the invention of *Hultgren* is to obtain exceptionally low values and still maintain reasonable heat transfer by using a pattern on the wall which provides a circulating effect on the flow, while keeping the turbulence either low or absent; this means operating in a low *Reynolds* number region. *Hultgren* achieves this by using ridges in the wall that have only a small angle to the direction of flow.

The present invention is an improvement on the *Herrmann* design but the improvement regards the distribution of the flows. In order to get a high efficiency for heat transfer between two flows of media, it is simply not enough to provide a large heat transfer surface area and a high heat transfer coefficient as the simple theory would prescribe.

If the two flows are balanced, i.e., they represent the same flow of heat capacity, then they could in theory (given great enough product of area and heat transfer coefficient) swap temperatures in the exchanger. The warmer flow would obtain the temperature of the colder flow and vice versa. However, if one flow is of larger heat capacity than the other, this temperature exchange can no longer be done because the amount of heat that can be accommodated by one of the mediums is not the same as the other medium. Only the medium with the lower heat capacity will ever reach the temperature of the other medium.

Since heat transfer is a localized process, it is not enough that the two fluid flows are of the same average heat capacity, rather the two flows have to be balanced over every subpart of the heat exchanger. Each and every strip of the heat exchanger wall area has to be contacted by the same amount of flow capacity on both sides. Otherwise, part of the one fluid medium will be saturated in temperature without

having fully changed into the temperature of the opposite flowing medium. This necessitates that the two flows must be balanced not only on the whole, but also to their parts, or else the heat transfer efficiency will never approach 100% regardless of its size and heat transfer coefficients.

In a similar manner, the heat exchanger efficiency will suffer from extra unbalances introduced by uneven flow distribution, especially when the two fluid flows are unbalanced. Thus, it should be appreciated that any tendency to form preferred paths for the flow on one side of a plate without the same preference being formed on the exact opposite side is detrimental to the efficiency of the heat exchanger.

The present invention ensures that the flows on both sides of the heat exchanger walls are evenly distributed so that no cold or hot pathways are formed, thereby resulting in a better overall heat transfer efficiency for the heat exchanger. The even flow distribution of the present invention is achieved by using a discrete pattern in the wall sheet such that the resistance to flow in the slots formed between two consecutive folds of the sheet is higher along the intended direction of flow than at a right angle to this direction.

Although *Herrmann* shows an accordion folded, patterned sheet, neither it, nor the other cited references discuss the flow resistance in different directions. While *Usher* and *Hultgren* show a flow pattern for providing lower pressure drop, that pattern will have more pressure drop at a right angle to flow, not less, as in the present invention. This can not make the flow distribution principle of the present invention obvious to a person having ordinary skill in the art.

For the above-stated reasons, the cited art does not render the present application obvious. Therefore, Applicant earnestly requests reconsideration and allowance of Claim 5.